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Air Evacuation of Thermally Injured Patients: Principles of Treatment and Results

RICHARD C. TREAT, M.D., KENNETH R. SIRINEK, M.D., Ph.D., BARRY A. LEVINE, M.D., AND BASIL A. PRUITT, JR., M.D.

During the 12-month period January through December 1978, 148 thermally injured patients were aeromedically transported to our burn unit by either helicopter or fixed-wing aircraft. One hundred twenty-nine patients (87%) were evacuated within 48 hours of injury. Treatment by a general surgeon and ICU nurse sent to the local hospital consisted of: insertion of 87 catheters, immediate pulmonary care in 20 patients, escharotomy in six patients, and adjustment of intravenous fluid administration in 42 patients. Thirty-six per cent of patients were considered too unstable clinically to transport until therapy had been rendered. No patients died in flight, and six per cent of all patients aeromedically evacuated were considered clinically unstable when they arrived on the burn ward. Overall mortality was not adversely affected by transportation of acutely burned patients over long distances.

Air evacuation of the critically ill patients by both helicopter and fixed-wing aircraft to regional medical centers is common in modern patient care (1, 2, 9, 12). The United States Army Institute of Surgical Research has been involved in the air evacuation of acutely burned patients since 1951. Prior reports have delineated the principles of treatment and necessary equipment and personnel (6, 7). The present report details both our experience and results in aeromedical evacuation of 148 patients transported during 1978.

MATERIALS AND METHODS

During a 12-month period, 1 January–31 December 1978, 268 extensively burned patients were admitted to the United States Army Institute of Surgical Research (Table I). Their mean age was 27 years; 74% of the patients were males. The mean total area of the burn was 32% of the total body surface (TBS), with an average 14% area of third-degree burn. Sixty-seven patients died, for an overall mortality of 25%.

One hundred forty-eight patients (55% of all admissions) were aeromedically transported to our burn unit by either helicopter or fixed-wing aircraft. In the majority of patients, flame burns were the etiology of their thermal injury (Table II). Fifty-five patients also sustained 73 associated injuries, the majority of which were inhalation injuries (Table III). The remaining 120 patients were admitted following ground transportation by both private and city-operated emergency vehicles. There was no significant difference in mean age, % TBS burn, per cent 3° burn, and mortality for patients admitted following either aeromedical evacuation or local ground transportation (Table I).

RESULTS

Flight Data. During 1978, 148 patients were aeromedically evacuated on 124 flights accompanied by a general surgeon and an intensive care nurse. The average round trip from the burn unit was 7.2 hours, with an average 3.7 hours spent in-flight (Table IV). For each flight, an average 1.2 hours was spent in the local hospital preparing the patient for evacuation while an additional 0.6 hour was spent in local ground transportation. For 129 patients, the burn team arrived on the average of 11.5 hours postinjury (Table V). The remaining 19 patients were greater than 48 hours postinjury and were evacuated to the burn unit on the average of 7.6 days postinjury.

Forty-three patients injured within a 200-mile radius (helicopter range) of the burn unit were evaluated by the burn team within an average of 6.8 hours postinjury (Table V). Forty of these patients were transported by helicopter; the other three were clinically unstable and

From the Department of Surgery, The University of Texas Health Science Center, San Antonio, and the United States Army Institute of Surgical Research, Brooke Army Medical Center, Fort Sam Houston, Texas.

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TABLE I
Patient characteristics

	All Admissions	Flight Patients	Nonflight Patients
Number	268	148	120
Male	198 (74%)	112 (76%)	86 (72%)
Female	70 (26%)	36 (24%)	34 (28%)
Mean age (yrs)	27	27	27
Mean TBS* burn (%)	(32)	(38)	(25)
Mean 3° burn (%)	(14)	(16)	(11)
Mortality (%)	(25)	(27)	(23)

* TBS = total body surface.

TABLE II
Type of burn injury

Flame		122
Gasoline, kerosene	48	
Structural fire	29	
Butane, propane	20	
Oil, gas well	13	
Motor vehicle	10	
Aircraft	2	
Scald		14
Electrical		10
Chemical		2
		148

TABLE III
Associated injuries in 55 patients

Inhalation injury	48
Urinary hemochromagens	8
Long bone fracture	6
Cerebral concussion	4
Major lacerations	2
Corneal burn	2
Carbon monoxide poisoning	2
Cardiac arrhythmia	1
	73

required mechanical ventilation. These latter patients were transported by fixed-wing aircraft.

Ninety-nine patients injured within the continental United States (CONUS) but beyond helicopter range were evacuated to the burn unit by 84 fixed-wing aircraft missions. Total mission, flight, and in-hospital hours for fixed-wing flights closely paralleled the mean data for all flights (Table IV). An additional six patients injured outside the continental United States (OCONUS) were seen by the burn team within an average of 20.9 hours following injury (Table V). Four fixed-wing flights for these six patients involved a two-to-three fold increase in total mission, flight, and in-hospital hours (Table IV).

Patient Data. During 1978, the U.S. Army Institute of Surgical Research was requested to accept in transfer 131 acutely burned patients (within 48 hours of injury). The referring physician was requested to insert intravenous and Foley catheters, and a nasogastric tube. Taking into account body weight and extent of injury, a rate of intravenous fluid administration was agreed upon according to the Brooke formula. The referring physician was further requested to have the patient's wound washed, and covered with available topical antibiotic cream, followed by an application of sterile dressings. Monitoring of the patient's peripheral pulses and possible escharotomy for limb salvage were also discussed. The diagnosis and treatment of an inhalation injury were reviewed. A chest X-ray and arterial blood gases, if available, were also requested.

Two patients died at their local hospital before arrival of the burn team. The remaining 129 patients were evaluated and treated at their local hospital by the general surgeon and ICU nurse from the burn unit before air evacuation. Initial treatment consisted of catheter placement, intravenous fluid administration, pulmonary care, wound care, and drug administration.

A total of 87 catheters had to be inserted, the majority being nasogastric tubes (33) and intravenous (29) catheters (Table VI). Eighteen patients had already required endotracheal intubation (17) or tracheostomy (one), and eleven of these patients were being mechanically ventilated. Following arrival of the burn team, the general surgeon found it necessary to insert an additional seven

TABLE IV
Flight data

	All Flights	Helicopter	Fixed-wing (CONUS)*	Fixed-wing (OCONUS)†
Number of flights	124	36	84	4
Number of patients	148	43	99	6
Total hours	7.2	3.4	8.1	20.6
Flight hours	3.7	2.2	3.9	12.6
Local inhospital hours	1.2	0.9	1.3	2.7
Local travel hours	0.6	0.2	0.7	0.7

* Continental United States.
† Outside Continental United States.

TABLE V
Comparison of mortality in patients evacuated within or after 48 hours of injury

	All Flights	Helicopter	Fixed-wing (CONUS)*	Fixed-wing (OCONUS)†
Within 48 Hours of Injury				
Number of patients	129	40	84	5
Injury to burn team arrival (hrs)	11.5	6.8	13.2	20.9
Mortality (%)	(26)	(25)	(26)	(20)
Beyond 48 Hours of Injury				
Number of patients	19	3	15	1
Injury to burn team arrival (days)	7.6	6.6	8.1	3.0
Mortality (%)	(37)	(0)	(40)	(100)

* Continental United States.
† Outside Continental United States.

TABLE VI
Treatment rendered at local hospital

	Initial Treatment	Burn Team Treatment
Catheters Inserted	359	87
Intravenous	125	29
Nasogastric	99	33
Foley	116	13
Endotracheal	17	8
Tracheal	1	2
Thoracostomy	1	2
Mechanical Ventilation	11	16
Wound Treatment		
Topical agent, dressings	111	38
Escharotomy	9	6

endotracheal tubes, to replace one, and to perform two emergency tracheostomies (Table VI). Two patients required tube thoracostomy for a pneumothorax sustained secondary to subclavian catheter placement.

Twenty patients required treatment of pulmonary complications when the burn team arrived (Table VII). Fourteen patients required immediate life-saving procedures. The other six patients required adjustment of their mechanical ventilators to correct hypoventilation.

Nine patients had had early escharotomies performed by local physicians for loss of peripheral pulses in an extremity. The burn surgeon found it necessary to perform escharotomy in an additional two patients, and to revise the escharotomy in four patients. Two of the 11 patients requiring an extremity escharotomy also required a chest escharotomy to relieve restrictive impairment of ventilation. Thirty-eight patients required application of antibiotic cream and sterile dressings prior to transportation to the burn unit.

Forty-two patients needed their intravenous fluids adjusted when the burn team arrived. Thirty patients were considered to be oliguric secondary to hypovolemia and required an increased rate of administration of intravenous fluids. Only 11 of these hypovolemic patients were also hypotensive. Four patients were considered to be hypervolemic and required restriction of their fluid input. Another eight patients had uncleared urinary hemochromagens which required treatment with increased intravenous fluid administration and mannitol.

On the basis of 68 treatment deficits (pulmonary, 20; intravenous fluid, 42; absent peripheral pulses, 6), 46 of 129 aeromedically evacuated patients (36%) were considered clinically unstable when the burn team arrived. When compared to patients evacuated by fixed-wing aircraft, patients evacuated by helicopter had a higher incidence of being clinically unstable at their local hospital (45 vs. 31%). Twenty-one of the patients considered unstable at local hospital subsequently died, for a mortality rate of 46%.

In-flight Patient Data. One hundred twenty-nine patients were aeromedically evacuated while receiving intravenous fluids and with functioning nasogastric tubes and Foley catheters in place. Three patients had tube thoracostomies with drainage to underwater seal during transportation. Twenty-seven patients were intubated and mechanically ventilated during air transportation. Seven of these patients required adjustment of either tidal volume, respiratory rate, or positive end expiratory pressure during the flight. An additional 13 patients received humidified oxygen by face mask.

Twenty patients required an intravenous fluid "push" during flight to treat episodes of oliguria (urine output less than 50 ml/hr) or uncleared urinary hemochromagens. The four patients who were considered to be hypervolemic at their local hospital continued to have their fluids restricted and maintained an adequate urinary output. Twenty-nine patients received intravenous medication during the flight consisting of: mannitol (eight), bicarbonate (three), narcotic (15), and pancuronium bromide (three).

Four patients were considered to be unstable clinically in flight because of hypotension. One patient responded to an increased rate of fluid administration while three remained refractory to all forms of therapy. All four patients subsequently expired at the burn unit from complication of the burn wound sepsis.

Burn Ward Patient Data. Eight of 129 aeromedically evacuated burn patients (6%) were hypotensive when they arrived at the burn ward. Five of these patients had been in shock at the local hospital, and three of these five patients remained in shock during air evacuation. Three patients were hypotensive only when they arrived on the burn ward. All three patients had had escharotomies at the local hospital and narcotics during the flight. Additionally, all were thought to be hypovolemic and behind on intravenous fluid administration during air transportation. Six of these eight patients who were hypotensive when they arrived at the burn unit subsequently died of sepsis for a mortality of 75%.

DISCUSSION

The concept of airlifting war casualties from combat areas existed as early as 1870 (5). The age of aeromedicine was born when men wounded in the siege of Paris were flown out by balloon. During World War II aeromedical airlift became a highly organized system developed from special techniques in both aviation and medicine (4).

TABLE VII
Types of unrecognized pulmonary injury

Respiratory insufficiency	8
Hypoventilation on respirator	6
Upper airway obstruction	2
Pneumothorax	2
Carbon monoxide poisoning	2
	20

Between 1942 and 1949, military aircraft transported 1.4 million patients with only 46 deaths occurring in flight (10). During 1954 to 1967, more than 65,000 wounded soldiers were airlifted with only seven deaths occurring in flight (3).

The potential of the helicopter as a means of forward air evacuation was first recognized during the Korean conflict. Its successful utilization accounted for a reduction in the mortality rate to 2.3% among wounded admitted to medical treatment facilities (8). Technical aircraft advances coupled with the placement of a medical corpsman on board the helicopter enabled reduction of this mortality rate to less than one per cent during the Vietnam conflict (3).

Air evacuation of critically ill civilian patients by both fixed and rotary-wing aircraft to regional medical centers was a logical development and extension of wartime experience. Civilian use of medical airlifting has included transportation of high-risk neonates as well as medical and surgical emergencies; but has primarily involved the evacuation of acutely injured patients (1, 2, 9, 12). In 1970, Roberts et al. reported an overall mortality rate of 26% following "medicopter" evacuation of 50 trauma patients (9). Cleveland et al. reported a 3-year experience with air evacuation of 2,650 patients (2). During 1974, they successfully evacuated 198 critical trauma patients with no flight-related deaths and a subsequent overall mortality of 20%. The overall mortality of 27% in this series of acutely burned patients closely parallels the subsequent death rate in the above mentioned series of patients with acute traumatic injuries.

The U.S. Army Institute of Surgical Research has been involved in air evacuation of acutely burned patients since 1951. Prior reports from this institution have delineated the necessity of proper equipment and trained personnel being sent to the local hospital to insure preparation and safe transport of each patient during aeromedical evacuation (6, 7). Other authors involved in transport of critically ill civilian patients concur, and emphasize that air transport without trained medical personnel on board has the same limitations as ground ambulance transport under similar conditions (2, 9). In this report, 129 acutely burned patients were transported to our burn unit without a single death occurring in flight. In addition, the burn team was able to clinically improve 38 of 46 patients considered too unstable to evacuate.

The principle of transportation of the burn patient within 48 hours of injury and before the onset of sepsis was delineated by Moylan and Pruitt in 1973 (7). Because most of their patients were evacuated from Indochina, only 31% of them arrived within that time frame. In 1977, Stein and Stein reported that they received 90% of their patients within 24 hours postinjury from local New York hospitals (11). In the present series, 87% of aeromedically transported patients arrived at our burn unit within 48 hours of injury. The magnitude of this percentage is readily appreciated by review of Table IV. The majority of patients (67%) were not from local hospitals and were beyond helicopter range. In addition, an average 3.7 hours were spent in flight for all 124 missions flown during 1978. Nineteen patients beyond 48 hours of the time of injury were transported without an in-flight death or medical emergency, and their subsequent mortality was slightly but not significantly (37% vs. 26%) increased (Table V).

The most frequently required task of the burn team at the local hospital consisted of the placement of 87 catheters for both treatment and monitoring during evacuation. In 12 patients, catheter insertion was considered lifesaving in the placement of endotracheal tubes (eight), tracheostomy tubes (two), and thoracostomy tubes (two). Sixteen patients had to be placed on a volume ventilator and six patients required escharotomy. This meticulous attention to adequate catheter placement, pulmonary care, and escharotomy was rewarded by the lack of problems in these areas during the flight. Twenty-seven patients were intubated and mechanically ventilated during flight without any technical problems.

The next area of immediate concern by the burn team involved the adjustment of intravenous fluids in 42 of 129 patients. The majority (38) of these patients were considered to be under resuscitated and needed a fluid "push" to increase urine output to 30 to 50 ml/hr or to clear urinary hemochromagens. Twenty of these same patients required an additional bolus of intravenous fluid during flight for transient episodes of oliguria. Moylan and Pruitt also demonstrated this increased fluid need in-flight and attributed it to increased evaporative water loss from the skin and lungs because of the low humidity in both helicopters and fixed-wing aircraft (7).

When all admissions were compared to either all flight evacuated patients or to ground evacuated patients, there was no statistical difference in mean age, mean TBS burn, mean area of third-degree burn, or in overall subsequent mortality (Table VIII). It would appear that aeromedical evacuation of patients with large thermal injuries over long distances can be accomplished without adversely affecting subsequent survival. The lack of difference in overall mortality between patients evacuated long distances by fixed-wing aircraft or patients transported short distances by helicopter further attests to the capacity of a well-trained team to move these patients

TABLE VIII
Comparison of extent of injury and mortality by mode of transportation

	All Admissions	All Flights	Helicopter	Fixed-wing	Non-flight
Number of deaths	67	40	10	30	27
Mortality (%)	(25)	(27)	(23)	(29)	(23)
Mean age (yrs)	38	37	33	38	40
Mean TBS burn (%)	(55)	(55)	(54)	(55)	(56)
Mean 3° burn (%)	(31)	(30)	(25)	(31)	(34)

safely in order to facilitate treatment at a regional medical center. Of significant note is that all patients who died independent of mode of transportation to the burn unit had a statistically greater total body surface burn (55%) and greater third-degree burn (31%) compared to extent of injury for the entire group.

The frequency with which alterations of hemodynamic and pulmonary management before patient movement were deemed necessary indicates that those aspects of care must be discussed in detail during the initial conversation and consultation between the referring physician and the burn team surgeon. The frequency of those needs also emphasizes the importance of immediate and complete assessment of the status of the patient as soon as the burn team physician arrives at the referring hospital. Similarly, the need for in-flight modifications of pulmonary and hemodynamic care speaks for close monitoring of those systems during the air evacuation procedure.

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DISCUSSION

DR. CHARLES HARTFORD (Crozer-Chester Medical Center, Upland, Chester, PA 19013): I would like to thank the authors for a fine presentation, and thank Doctor Treat for providing me with a well-written manuscript. I think this paper is important, with several subtle messages, and I would like to discuss several issues.

Among other things, the paper looks at the care delivered before the physician with a special interest or expertise gets a chance to treat the patient. The large number of changes that needed to be made and the relatively high incidence of instability that the authors found may be a serious indictment of our ability to get the message across to our colleagues in the field. For instance, the principles of fluid resuscitation are quite simple, and the ability to effectively resuscitate the majority of patients in this clinical setting is quite easy, so that this result is disappointing. But it is not much different than the findings we had in the assessment of our hospital transfer program.

[Slide] When the Crozer-Chester Medical Center opened its burn care facility in 1973, it also established an interhospital system of transfer of patients in which the transport vehicle (a helicopter-land ambulance), and a physician (usually a resident) and an experienced burn nurse were sent to the referring institution to evaluate the patient, make changes, and then return with the patient. We studied 122 consecutive patients, all transferred within 24 hours, and 89 of them were transferred by the helicopter method.

[Slide] We also found it necessary to make changes in one third of our patients, and those changes are listed on this slide.

[Slide] With this kind of preparation, however, virtually all of the patients arrived in excellent clinical condition except in one sphere. This slide has to do with those patients who had respiratory tract injury. You will see we had eight patients who arrived at our burn care facility with respiratory acidosis. Looking at them more carefully, these patients were managed with either an Ambu bag or a pressure-limited respirator, which were totally ineffective.

As a consequence of this, we recommend the use of a volume-limited respirator. I would like to ask Doctor Treat if they used the volume-limited respirator in the helicopter.

The last matter I would like to address has to do with the doing of an escharotomy before arrival at the definitive treating institution. I think it is quite difficult to tell on clinical grounds or by eyeballing which extremities need escharotomy, and I think the time has come when we need to address this issue from a direct tissue pressure measurement standpoint. Also, they found that the escharotomies had to be revised in a significant number of patients.

Last, there is the not inconsequential problem of bleeding which occurs as a consequence of escharotomy.

I enjoyed the paper. Thank you.

DR. RICHARD C. TREAT (Closing): Thank you very much, Doctor Hartford, for your comments.

With regard to the use of a volume respirator in the helicopter, we have evacuated two or three patients utilizing the Bird ventilator with an H tank in the helicopter for very short periods of time very early in their burn course when compliance was not a problem.

An additional three patients during the year were in the short-range distance and the burn team was flown out by helicopter. These patients were found to have significant respiratory problems, and instead of flying them back in the helicopter with the risks of a pressure-limited ventilator, at that time we called on the Air Force to provide us with support of the C9 aircraft and the volume ventilator for transporting those patients.

I wish to thank the Association for the opportunity to present these data.